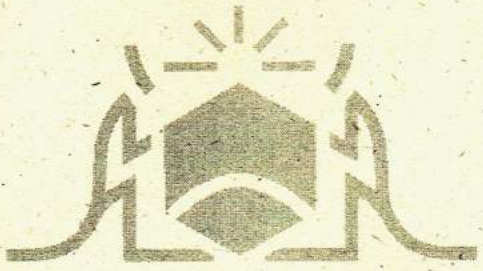
The Institution of Engineers, Australia

Western Australia Division



The Role of Renewable Energy in WA's Economic Future

Peter Hopwood BE PhD FIEAust CPEng

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Retiring President's Address

by

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2000 President
WA Division
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PART 1

Summary

This paper attempts to draw together several themes: the economic future of Western Australia, renewable energy technology, and climate change. In doing so it recommends that Western Australia take up renewable energy on a much greater scale than heretofore. Western Australians should "pick a winner" in the interests of future wealth generation in the State through using, developing and promoting renewable energy technology.

Western Australia has had a long interest in renewable energy. From the 1970's on, WA has had one or more government bodies charged with conducting or supporting research and development, or setting up demonstration projects, all aimed at exploiting the State's abundant wind and solar resources. Since the agreements on world climate change in the 1990's the state has committed further resources to renewable energy, and private enterprise has brought to fruition several innovative products. In spite of this, however, the industry's contribution to energy demand remains minute when compared to conventional power generation and the vast petroleum resources of the State.

In the 1960's Western Australia ceased its economic dependence on the rest of Australia when export restrictions on iron ore were lifted, and the great minerals boom began. Other mineral commodities soon joined iron ore to help Western Australia become the producer of more than 25% of the nation's exports. Since those times other countries have developed their own resources, often with Western Australian expertise. Most of Western Australia's major exports are now sold more often than not into a buyer's market, and as new technology and conservation take hold in the developed world the market for Western Australia's

commodities may remain difficult, perhaps even decline. In the face of this possibility Western Australia should take every opportunity to expand its "product mix".

Global climate change and the need for sustainability in our future behaviour both point to increased use of renewable energy technology, around the globe. European countries and the USA are significant investors. Because of our natural advantages, Western Australia can become a contributor to this emerging industry before it is too late.

Renewable energy technology offers Western Australia an opportunity to be significant in a high-growth industry. As WA grows in population and environmental demands in the 21st Century, renewable energy can become integral to our lifestyle and our economic well-being. This paper recommends action on this front in the life of the next State Government.

The paper is in two parts: the first addresses the main theme of the paper; the second describes several renewable energy technologies, and is provided for those less familiar with the current state of these interesting approaches to generating energy without affecting the environment.

WA Experience with Renewable Energy

Renewable energy, in the form of wind, has long been a feature of farming in WA – the ubiquitous Southern Cross wind-driven water pump. Other, long-used forms of renewable energy such as hydro-electricity were not so relevant in earlier times in WA, because of the terrain and the low rainfall, although wood was burned [1] to power the boilers that drove the pumps on the Goldfields water pipeline.

Photovoltaics [2] were first introduced in the USA in 1955, by which time semiconductors had been developed, and the ability of a P-N junction to respond to light was discovered. Early PV cells had efficiencies of around 5%, one-third of what is now the norm for commercial units. In the 1980's Solar Sales Pty Ltd, a small WA company, began assembling PV panels from imported cells and other components, ceasing manufacture in favour of importation around 1990.

In the 1960's at UWA's Department of Mechanical Engineering, post-graduate student Peter Cooper undertook theoretical and experimental investigations into solar distillation as a means of producing fresh water from saline. Dr Cooper joined CSIRO from university and continued this research for some years. To date this technology has not been found to be economic, but the idea should not be forgotten; new materials and different circumstances could make the concept viable.

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[1] It was not replaced with new plantings, however; the areas around the pump stations were cleared of all significant tree growth.

[2] PV

After the energy crisis of 1974, Australia committed large sums to fund research and development programmes in renewable energy. The State Government established SERIWA [3]. This body managed grant funds that were applied to projects proposed by research teams from tertiary institutions, government departments and private enterprise. A body of knowledge built up over the years, some of which remains relevant today. As memories of the oil shortages faded, governments in the mid-1980s cut back their R&D support. SERIWA was one Government-funded body to feel the impact. During this time Rottnest saw the installation of early designs of wind turbines, and another unit was established at Woodman Point. These units were inefficient and uneconomic, and were de-commissioned some years later.

To preserve the research experience that had made Western Australia a leader in the renewable energy field Murdoch University researchers who had collaborated with SERIWA promoted the formation of a self-funding energy research institute, and MUERI [4] was formally established in 1987.

The Wellington Dam near Collie was built in the late 40's. A 4MW hydroelectric unit was installed at the dam, connected to the southwest grid. Expansion to 8MW is possible. The Ord River Dam was built in the 60's, and at the time its hydroelectric potential was well recognised. Only with the advent of sufficient demand in the region, through the Argyle Diamond Mine, was it economic for a power station to be built at the dam; a privately operated unit of 30MW capacity is now in operation.

In 1993 UNIDO [5] promoted its concept of "centres of excellence" in technologies relevant to developing nations; renewable energy was identified as one of these. After considering various developing countries as the base for its first such cen-

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[3] Solar Energy Research Institute of Western Australia

[4] Murdoch University Energy Research Institute

[5] The United Nations Industrial Development Organisation

tre, UNIDO was convinced by the State Government that WA was a better choice. Subsequently UNIDO, the WA Government and the Commonwealth Government agreed to create the "Perth International Centre for Application of Solar Energy" [6]. CASE is a statutory authority, and was established under an Act passed in July 1994. CASE has various objectives to suit its stakeholders: assisting developing nations, particularly rural women (UNIDO's objective); promoting the use of renewable energy in aid programs (Commonwealth objective); and developing international business opportunities for Western Australian manufacturers and service providers (the State's objective). Its operations have largely taken place in the region, particularly in Indonesia, Sarawak and Thailand, and in spite of its modest budget and the impact of the Asian economic downturn, CASE has managed to meet its stakeholders' objectives with some success.

In 1995 the Commonwealth called for bids to establish a cooperative research centre [7] for renewable energy. Murdoch University mounted a campaign to win the CRC, and was successful, with State government support. ACRE [8] came into existence in 1996, targeting several programs of research, training and technology demonstration. More recently ACRE has added policy development and advice to its portfolio, with some streamlining of its research program.

In 2000 two of Western Australia's fledgling renewable energy technology companies took advantage of conditions within the investment community and raised funding via public share offerings, two of the first Australian companies to do so in the field of renewable energy. Long before this time, however, WA became (and remains) pre-eminent in the design and manufacture of solar hot water systems. Companies such as Edwards and Solahart have generated significant export income and have taken large parts of the water heating market in other states of Australia.

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[6] CASE. The author is the non-executive chairman of CASE.

[7] CRC

[8] Australian CRC for Renewable Energy

Western Power (in its former guise as the State Energy Commission of WA) installed several modern wind turbines near Esperance, connecting these to the local grid. After the site capacity was expanded with larger units, the Esperance wind farm was for many years Australia's largest. Another unit was installed at Denham on the northwest coast. Western Power used these stations as a source of power and a means of gaining operational experience. Building on the success of the Esperance wind farm, in 2000 Western Power committed to constructing a 12.6MW system near Albany, comprised of 7 1.8MW units. These machines will be almost the largest available commercially at this time, and should be operational within 18 months.

Western Power has also recently committed to a power station designed to burn oil mallee timber. This will be a sustainable operation with additional benefits in terms of salinity management, given the oil mallee's tolerance to saline conditions.

For decades the tidal power potential of the Kimberley region of WA has intrigued public and private enterprises alike. The fundamental problem in earlier times was finding sufficient demand to warrant the expense of a tidal power station; more recently, the environmental impact of such a plant has been recognised. The most recent proposal centred on the tidal flats around Derby and comprised an innovative "double lagoon" concept designed to maintain power generation between tidal movements. While this concept gathered significant support from politicians and the general public, its economic return fell short of another proposal based on fossil fuels.

A large landfill site between Subiaco and Nedlands, the "Brockway tip", was decommissioned in the 80's and covered. The processes of decay within the landfill were found to give rise to recoverable combustible gas, predominantly methane. This gas is used at the Challenge swimming complex as a source of heat and electrical energy [9]. This form of renewable energy is termed "biogas".

electrical energy [9]. This form of renewable energy is termed "biogas". A similar application is that constructed at Woodman Point by the Water Corporation, where gas generated from sewage sludge digestion is used as fuel in gas engines to generate electricity. The wastewater treatment plant is a net exporter of electrical energy to the Western Power grid.

The above brief survey demonstrates the long term and diverse nature of Western Australia's use and development of many forms of renewable energy technology.

Climate Change

The concept of climate change resulting from mankind's impact on the global environment emerged in the early 1970's, when the "Club of Rome" (a group of eminent environmental scientists) predicted that man had irreversibly started the process of global cooling. Mankind's potential impact was by 1979 thought to be global warming, through the "greenhouse" effect, but there was little evidence available at that time. By the mid-'80's carbon dioxide levels were detectably rising in the earth's atmosphere, and as satellite monitoring of the earth's environment became more sophisticated and complete, changes in ozone levels in the upper atmosphere became known. The chemistry of hydrofluorocarbons and ozone was studied, leading to the worldwide banning of these chemicals as propellants in spray cans. In 1990 the Second World Climate Conference presented the results of work undertaken from 1988 by a group of scientists known as the

[9] This source of renewable energy is not continuous if the organic material is not replenished and managed. In recent times the amount of gas recovered from the old landfill site has declined, and is supplemented by natural gas from the city gas reticulation system.

Intergovernmental Panel on Climate Change. The panel estimated that a 60% cut in emissions would be required if atmospheric CO_2 levels were to be stabilised at the 1990 value. The early '90's saw considerable argument as to whether global warming was occurring, and the existing mathematical models of the global environment then differed widely in forecasts of what would occur regionally. In 1995 the Intergovernmental Panel reported that human influence on climate change was discernible on the balance of the evidence.

"Kyoto" is the now common way of describing the international meeting at which Australia and other developed nations committed to limit greenhouse gas (GHG) emissions, as suggested by the Intergovernmental Panel on Climate Change. The meeting took place in Kyoto, Japan in 1997, with commitments enshrined in the "Kyoto Protocol". The protocol has yet to be ratified by all industrial countries, most importantly by the USA, the largest of all producers of GHG emissions.

The Protocol is vague in several areas important to policy-makers. These include:

- What form sanctions would take;
- How targets might be re-negotiated;
- Why countries should be disadvantaged by the economic impact of meeting Kyoto commitments regardless of cost, when there are no defined cost benefits for so doing;
- How to prevent GHG-emitting industries departing countries with commitments for countries without, often with a net increase in global GHG emissions;

- Whether benefits accrue to a country supplying a low-GHG gas [10] to another where a high-GHG fuel is replaced, and if they do, in what form.

The Australian Greenhouse Office within the Commonwealth Ministry of the Environment has closely debated these and many other issues, but the outcomes are still not clear in the international environment. The USA's reluctance to ratify the Kyoto Protocol, if permanent, may trigger serious trade repercussions, some of which might affect WA negatively.

In response to Kyoto the Commonwealth government committed Australia to achieving renewable generation of 2% of all electricity used by Australians in 2010. For some States (e.g., Tasmania) this is easy to achieve, but nationally this is a substantial target. For WA in particular, further major investment is required to lift the renewable component of our electricity generation capacity.

"While there is substantial variation in the nature and extent of [the] possible effects [of global climate change], there is no doubt that the potential threats are a major international issue, and they constitute a huge challenge to national and regional environmental and economic policies and strategies." [11] WA must play its part, as our economy is energy-intensive, and our current renewable energy capacity is small.

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[10] This is a central question with respect to the North West Shelf LNG trade. To produce the LNG WA must emit considerable volumes of GHG, firstly as associated CO_2 which is separated from the hydrocarbons, and then in the generation of power and process heat, by burning a proportion of the hydrocarbons. WA's customers benefit by reducing their GHG emissions through the use of high thermal efficiency gas turbines fuelled with WA gas; WA's GHG emissions rise through producing the gas. If credits cannot be traded freely WA might not be able to expand its vital natural gas production facilities.

[11] Western Australian Technology & Industry Advisory Council, "Drivers and Shapers of Economic Development in Western Australia in the 21st Century", September 2000

WA's Economic Future [12]

The world economy is thought to be undergoing fundamental change, from "industrialised" to "knowledge". Some observers contend that the era within which we now live will one day be thought to have been as significant as the Industrial Revolution. Globalisation, e-commerce, market de-regulation and environmental pressures are supposedly leading to a different type of economy, one that is based much less in traditional production of commodities and much more in services.

If these contentions prove accurate, current trends may have adverse consequences for Western Australia, given the form of its economy. Since 1960 our wealth has depended upon development of our abundant and diverse mineral resources, and upon agriculture. If the global economy is trending away from our staple products, it is argued that WA must transform its economy by embracing new products relevant to the emerging economy. This is not to say that minerals production and processing should be abandoned; rather, the current strong performance of these industries should underpin the State's expansion into other areas of endeavour. Because Western Australia's economy lacks the diversity of some other Australian states, failure to adapt to the new economy may have more adverse impacts in WA than elsewhere. The TIAC [13] paper argues that WA must act soon to change its economic base to suit future needs, or else it will lose any advantage it might have as being an "early mover", with severe consequences for the State's economy in the longer term.

The current State government, like all since the 1960's, has ministries devoted to industrial and resource development. "Downstream processing" has been an ob-

[12] Much of this discussion relies on the paper published by TIAC, see footnote 11

[13] TIAC paper, see footnote 11.

ligation of major minerals producers, but the commitment has been virtually impossible to implement for economic reasons, particularly the cost of energy in WA compared to elsewhere. Diversification has been contemplated and promoted, but the State's manufacturing base is small, as is its on-going research and development effort, especially outside the universities. Since the 80's WA has been promoted as a centre for offshore engineering and construction, but has failed to overcome the competition from near neighbours such as Singapore. Jervoise Bay, originally built to support the offshore oil & gas industry, has become a centre for shipbuilding and ship repair. The State government initiative of recent years, to create a centre of excellence for marine industries based at Jervoise Bay, has yet to bear fruit for want of major investors willing to take on the risks such a concept presents. [14]

The TIAC paper considers environmental issues as they affect WA and as they might positively impact upon the State's economy. Key diversification strategies are suggested, including:

1. "Earth repair – restoring and rehabilitating degraded and polluted ecosystems;

2. Environmental survey – assessing, monitoring and auditing ecosystems;

3. Resource renewal – reduction, reuse, recycling of what is traditionally known as 'waste';

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[14] This last, so far unsuccessful attempt by the State to "pick a winner" exposes a weakness of the TIAC paper. Having quite thoroughly analysed the State economy in terms of emerging global trends, it proposes a way forward comprised largely of further studies. Exactly how this community should proceed to find and bring about a leading-edge industry needed within the new economy is not clear from the report, nor is it proposed as a topic for further study. Perhaps such criticism is unfair, as the "how to proceed" question might not have been part of the study brief, but the question has to be answered.

4. Sustainable energy – researching, developing and marketing energy products that are based on renewable resources, and improving the efficiency of current energy systems through better process technology and conservation;

5. Sustainable communities and cities – integrating the work of architectural, building, industrial design and planning professions in the design and construction of a sustainable built environment; and

6. Sustainable agriculture – producing and processing food that is uncontaminated by toxic substances, pesticides and radioactive materials." [15]

None of these suggestions is uniquely available to Western Australia: most developed nations are pursuing similar objectives, often with much greater commitment than WA alone can muster. Not all of the strategies suggest a mature export income of the order of that generated by any one of our major minerals at present. Sustainable energy does, however, present an opportunity to diversify our industrial base in a significant and rapidly growing area of technology application.

At the time of writing the Australian Prime Minister is reportedly [16] preparing to announce a major Commonwealth initiative in innovation, centred on the concept of major research facilities (MRFs). The Commonwealth is expected to commit up to $0.5b to a series of MRFs to undertake leading-edge research in specific areas. IT, biotechnology, nanotechnology, and medical research are suggested. Apparently the Commonwealth will match State and industry contributions 1 for 1, so up to $1b may be available for work in the selected areas. Conceptually an MRF would include government agencies such as CSIRO as well as universities, CRCs, and industry. If this Commonwealth initiative eventuates as described it presents

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[15] This list of desirable characteristics of sustainable agriculture does not mention genetic engineering, which is interesting.

[16] Bulletin, 16 January 2001, p24

WA with the opportunity to combine its disparate interests in renewable energy generally into a bid to create a renewable energy MRF in WA.

In summary, WA should be preparing to diversify its industrial base to include more of relevance to the emerging "knowledge" economy. Renewable energy technology presents an opportunity to do this, building on the experience already here. Commonwealth initiatives in increasing the level of innovation within Australia could be exploited to create a renewable energy centre of excellence for the nation in WA.

The Role of Renewable Energy in Western Australia's Economy

Long after many other parts of the developed world WA introduced "green power" as an option for consumers. The use of renewable energy sources will expand as the funding from the surcharge flows through to new developments. This is a welcome initiative from Western Power, but it is essentially incremental; more radical decisions will be needed for WA to achieve Australia's objectives in terms of renewably sourced electricity by the end of the decade. Committing to larger projects offers local manufacturers and engineering services providers to develop expertise in renewable energy, building our export potential in this industry.

Considering the potential for some forms of renewable energy technology in WA, we should focus on using wind, photovoltaic, solar thermal, biomass and ocean (tide, wave) technologies. Research and development in wind, ocean currents, hydrogen storage and distribution should be rewarding. Enhancing our existing strong position in solar water heating and inverter technology must be a priority. Developing further applications for renewable energy (for example, desalination) should also be supported.

The basic material in photovoltaic cells is silicon, dosed with other elements including rare earths. All of these materials exist in abundance in WA. We have the technical skills in WA to establish a photovoltaic manufacturing facility here, at about the same capacity Japan had in 1995, 20MW. By the end of this decade WA could produce as much as Japan did in 1999 (80MW). Given that photovoltaic panels sell for about US$8m/MW, by the end of this decade we could conceivably have an export income of over $1b in photovoltaic products and systems [17]. There is no reason apparent to this writer why such an outcome is impossible for WA; if Japan can do it through a period of stagflation, with our optimism and export orientation we can do the same.

WA has unsurpassed solar and wind resources. We have minerals in abundance, and technical skills generally equal to the best. Renewable energy and the hydrogen economy are industries of the future. We need to diversify our economy, and to counteract any criticism we might receive due to the climate impact of our existing major industries.

WA could become the renewable energy centre of excellence for Australia. WA could combine its many initiatives in renewable energy into a coherent, end-to-end developer and supplier of several key parts of the industry. Diversification of the economy by building this industry would be timely in the context of global climate change and global environmental politics. WA should "pick a winner" by adopting renewable energy in every possible way. We should be planning to create another $1bn of export revenue for WA from the renewable energy industry by the end of the first decade of the 21st century.

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[17] By comparison, WA's rock lobster industry was worth $300m in 1999.

PART 2

Renewable Energy Technologies

There are fundamentally three sources of renewable energy available to mankind: geothermal energy, flowing as heat from the earth's core to its surface; tidal energy, arising from the relative motion of the earth and the moon (in the main); and solar energy, radiated from the sun. Various natural mechanisms based on solar radiation allow mankind to access solar energy in various ways – wind, thermal, biogas, biomass, ocean currents.

The technologies for producing useful energy range from entirely practical to conceptual. This section of the paper briefly reviews the more practical technologies, highlighting those relevant to WA.

All diagrams and pictures in this part of the paper were obtained from the Internet. The author particularly acknowledges and recommends two sites: the first is the Australian Greenhouse Office (www.renewable.greenhouse.gov.au) site; the second is the Danish Wind Turbine Manufacturers' Association site (www.windpower.dk). Other useful sites worth visiting are those maintained by the WA Office of Energy (www.energy.wa.gov.au), the British Wind Energy Association (http://www.britishwindenergy.co.uk/), and the US National Renewable Energy Laboratory (http://www.nrel.gov/).

Wind

Hydro-electricity has been a major contributor to power systems worldwide over the last century. Countries more mountainous than Australia have exploited this

form of renewable energy, often in lieu of fossil fuelled power stations. In Australia the Snowy Mountains Scheme immediately after WW2 was then in some respects a nation-builder, and it continues to support the interconnected grid covering NSW and Victoria, and extending to Queensland and South Australia. In more recent times there have been far fewer major hydroelectric stations built, because the environmental impacts of inundation and reduced river flows are now recognised. The prospects for further major hydroelectric power generation in Australia are poor. Mini-hydro and micro-hydro (kW scale) systems will continue to be used where appropriate.

Wind power is another successful form of renewable energy with a long history. The Dutch harnessed it for grinding grain in their famous windmills; WA farmers use it to pump water. About 20 years ago Denmark decided to "pick a winner" in the form of modern wind turbines, creating what is now a major industry in that country, both for domestic and export markets. A recent Danish design for use offshore (but installed onshore for testing purposes) generates 2MW; it is shown below.

The vehicles parked at its base indicate the scale of this machine. The picture also shows two pads for additional machines; as can be seen, they are quite close to the first turbine. To put this in context, this single machine produces almost as much power as the entire system at Esperance; three such units could supply any town in WA with a population less than about 3,000, which is most of them! Denmark had no natural advantage when it embarked on creating an industry in wind power. Perseverance, government support (through directed purchasing arrangements, R & D effort, etc.) and competent engineering have brought Denmark to its current position as a world leader in wind power.

How successful is modern wind turbine technology? Sitting here in far-off WA we are oblivious to the rapid pace of take-up of wind in other countries. Europe is the world leader in wind energy, with more installed capacity than any other region of the world. By the end of 1999 Europe had installed over 8,500MW [18] of installed capacity - more than double the figure for 1996. This growth trend is expected to continue, as wind is the fastest growing renewable energy technology worldwide. Growth in the USA is also significant; over 1,000MW has been installed there.

Improvements in wind energy technology mean that the trends that have led to the dramatic fall in the cost of wind energy are set to continue. Countries all over the world are setting targets for wind power. It is estimated that 22,000MW of wind energy capacity, in the form of 40,000 wind turbines, will be installed in the next 10 years. This represents an annual market of around ECU 2.4 billion. Europe is the hub of this global business, with six companies supplying over half of the world's turbines global wind energy market. Europe stands to benefit greatly from this move towards sustainability.

Europe is also leading the development of offshore wind farms, which benefit from the more constant and reliable wind resources found at sea. As an example, a 40MW wind farm has recently been commissioned at Middelgrunden in Denmark. This station

- Was built November - December 2000;
- Has 20 wind turbines, rated power 2 MW/400 kW each, with active stall power control;
- Has a hub height of 64 m, and rotor diameter of 76 m, rotational speed 17/11 RPM

[18] The total installed capacity of Western Power Corporation is about 3,200MW, and the maximum load ever met by Western Power was 2,508MW in the summer of 1999-2000.

- Has turbines spaced 183 m apart; and
- Is in a water depth of 5-10 m.

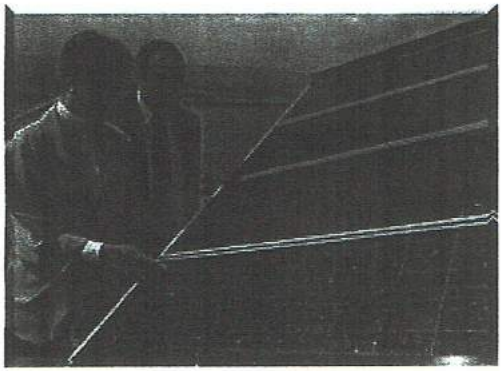
The station is about 2km offshore. Imagine such a station installed in shallow waters between Fremantle and Rottnest; "The Windmills" could take on new meaning!

The wind resources of WA are thought to be sufficient to power all of Australia, not just this state. WA could do much more to harness this vast, renewable source of electrical energy. We have a small turbine manufacturer [19], selling quite successfully. Let's build on that success in the future.

Solar – photovoltaic

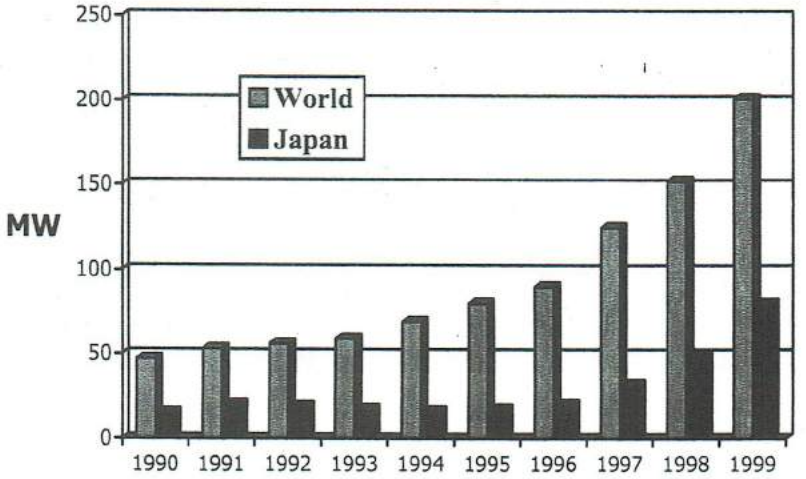
Photovoltaic cells were first demonstrated in 1955 in the USA. Only three years later they were applied to power an early satellite – "Vanguard 1" – and with increases in conversion efficiency to 10% by the late '50's, PV cells became ubiquitous for small power demands and remote locations. In WA, apart from imported consumer products, PV cells are widely used in telecommunications; examples such as the BHP and Hamersley railway signalling systems in the Pilbara, and the emergency telephones on major roads are well known to most WA engineers.

[19] Westwind



PV has been a key component in the development of RAPS [20] systems in WA. Presently all PV used in WA is imported or comes from BP Solar in NSW. The market for PV is much smaller than for wind, but it is growing rapidly, as shown in the following figure, obtained from the Japanese Society of Mechanical Engineers:

[20] Remote Area Power System



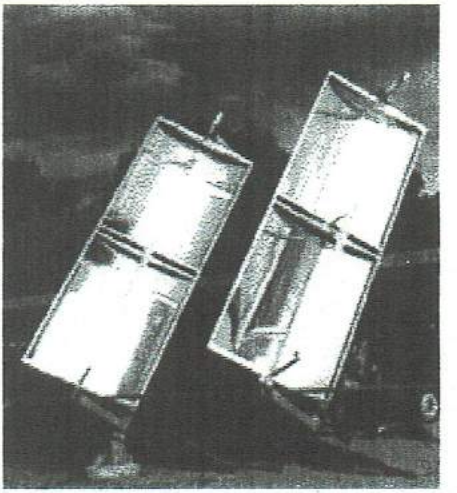
Growth is forecast to continue at comparable rates over the next ten years. In addition, new and more efficient technologies are expected to enter the market within that time.

Solar Thermal

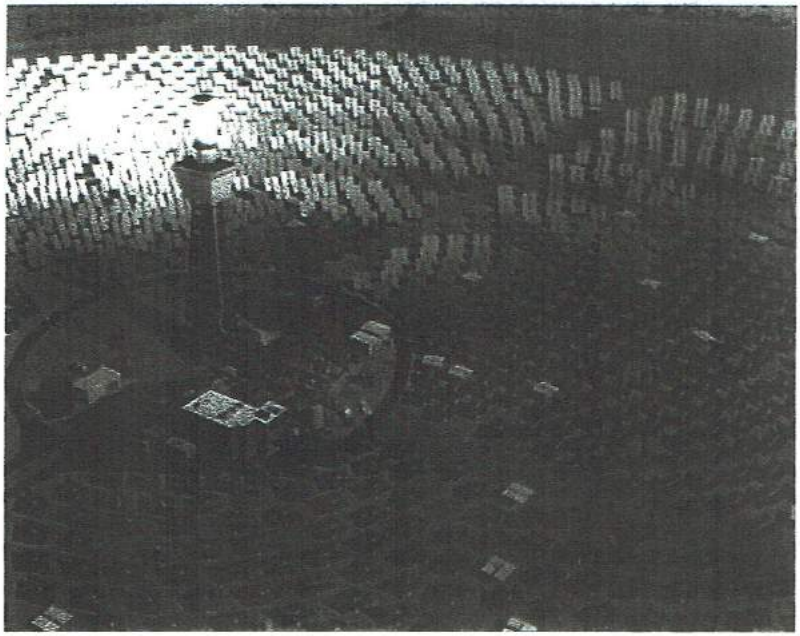
Boys using magnifying glasses to focus the sun's rays on hapless insects apply the principles of solar thermal renewable energy technology. In the engineering world we normally use reflectors, either parabolic or flat. Sometimes the mirrors track the movement of the sun, requiring greater sophistication (and cost).

The Australian National University has a successful solar thermal tracking mirror which generates electricity via a steam turbine, with the steam being created in a boiler at the focus of the mirror. The ANU machine (shown above) generates about 50kW virtually from dawn to dusk. Arrays of such machines could generate useful quantities of power, especially for our very sunny communities. Coupled with energy storage, solar thermal systems are a demonstrated technology ready for application.

An alternative design is the trough collector, shown below. Easier to manufacture, and to steer towards the sun, trough collectors are familiar in many countries, including India. A unit is in place at the Rockingham campus of Murdoch University. Trough collectors are also being developed at ANU; two units at that university are shown in the following photograph. These units are entirely practical, and easy to deploy and use at remote sites. They could be designed and produced in WA with current engineering expertise and manufacturing capability.



Flat mirror solar thermal power systems have been the subject of heavy investment in the USA. Their large-scale investments are typified by the "Solar 2" station, shown below.

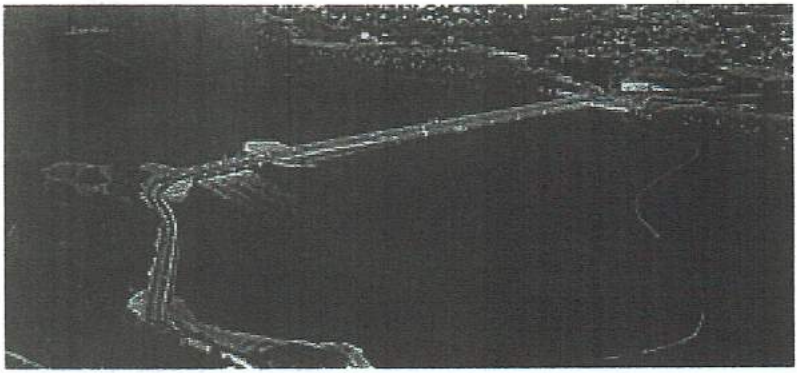


In this system the flat mirrors arrayed around the tower individually track the sun, reflecting the sun's rays on to an absorber / collector at the top of the tower. Very high temperatures are created, and electricity is generated, usually via steam turbine. Such systems are not yet economic, but are a useful research tool, potentially leading to practical generation systems in the future.

Tidal, Wave, Current

Tidal power generation has been an elusive technology. Only the French have managed to operate a practically sized tidal power station, at La Rance, on the coast of Brittany (see next photograph). While WA has high tidal range in the Kimberley region, the power demand there is currently insufficient to justify a

tidal power scheme when gas and diesel systems offer greater flexibility and reli-



ability. Nevertheless, tidal power in some form may come to WA in the future.

Wave energy has proven difficult to exploit. Several concepts have been tried, usually with physical failure of the devices occurring fairly quickly after deployment [21]. However, in November 2000 the intriguingly named LiMPET [22] technology for generating electrical energy from wave action was connected to the grid on the Scottish island of Islay, far to the west of Glasgow. The first unit, with a capacity of 500kW, is shown in the photograph below. 400 houses on Islay are powered by this machine, which creates an oscillating air column within the concrete enclosure and generates power via turbines in the incoming and outgoing ducts behind the unit.

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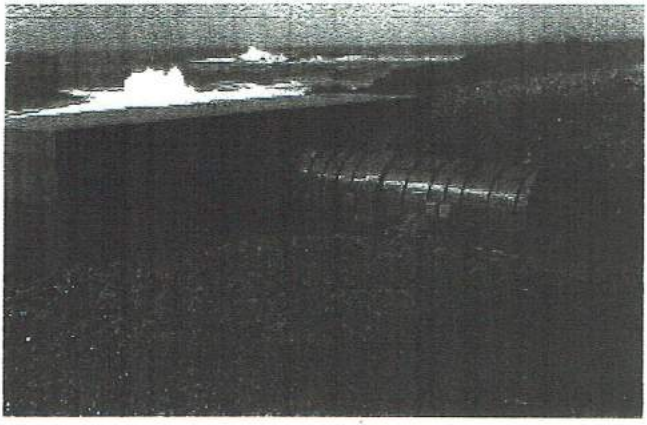
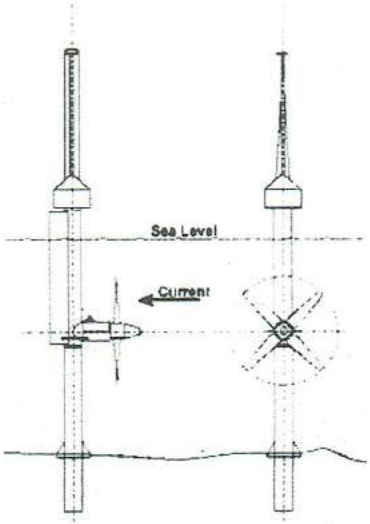
[21] However, as my predecessor Mr Dan Ryan demonstrated in 1999, engineers learn more from mistakes than successes!

[22] Land Installed Marine Powered Energy Transformer



Such units could be installed on our coastline where suitable foundations and wave conditions exist. We have significant wave energy resources along the south coast. LiMPET units would operate at night, when solar systems do not, a particular advantage.

Ocean currents also offer enormous renewable energy resources. Devices similar to wind turbines but fixed to the seabed have been proposed, to extract energy from ocean currents. Unfortunately most ocean currents flow at velocities below the minimum for economic exploitation, which is currently 2 to 3 m/s (4 to 6 knots). A machine for shallow waters and such currents is shown in the following diagram:



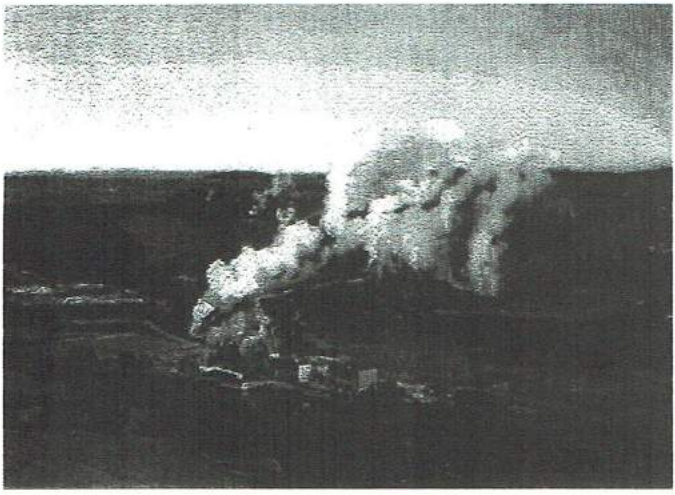
Such units could be deployed in specific locations, one of which might be the Dawesville Cut, where high currents are often observed.

An obvious area of future research would be to develop a device which is economic at typical ocean current speeds of about 1 knot (0.5m/s). WA could be a leader in such research, if it chose to devote the resources. We have a permanent north-to-south current, the Leeuwin Current, which flows past all the coastal population centres of WA, from Exmouth to Albany. If we could access a minute proportion of the kinetic energy in this current WA would have all the electricity it needed.

Geothermal

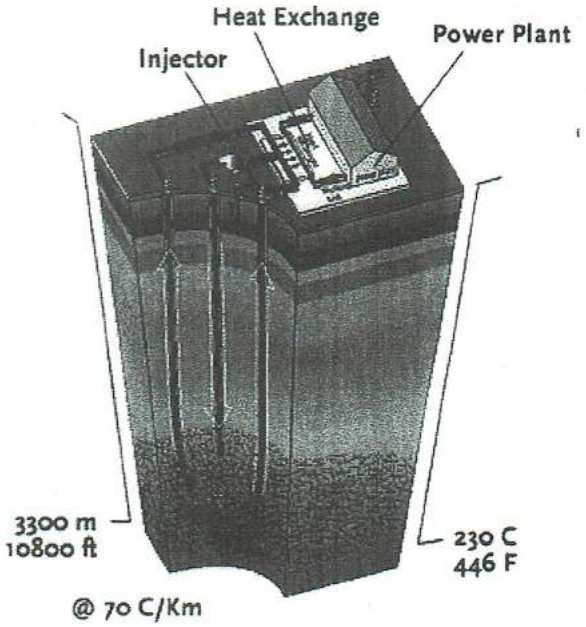
Geothermal power has long contributed to New Zealand's power demand. Stations such as Wairekei (pictured) use "wet" geothermal energy, i.e., the energy in

hot water naturally produced underground in volcanically active areas of the



earth. Such resources do not exist in WA, however.

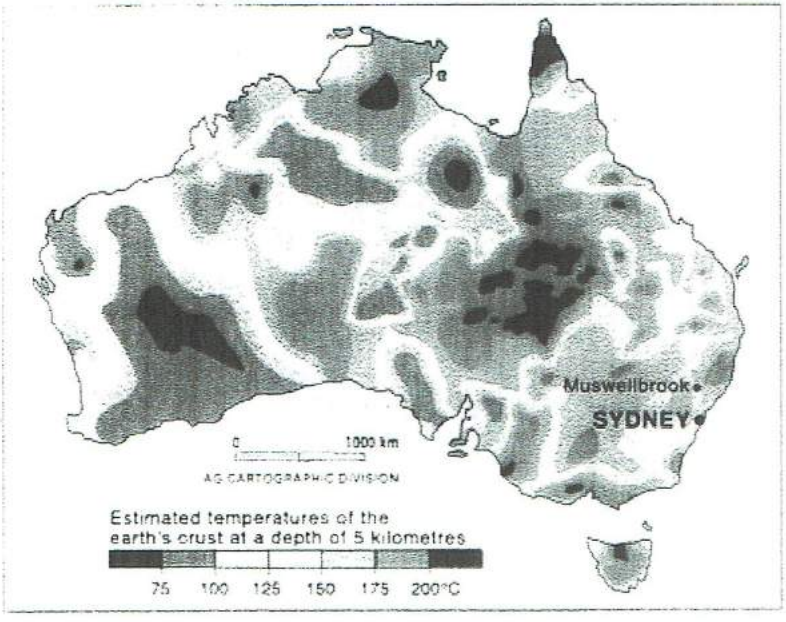
Another form of geothermal energy is called "dry" geothermal, or "hot dry rocks". In this scheme, shown diagrammatically below, two or more wells are drilled into a region of high temperature rock, and hydro-cracking is used to create fissures linking the two wells. Water is then pumped down one well, and hot water flows up the others. After some time (a few years) the volume of rock accessed by the wells cools, so the wells are plugged back a hundred metres or so, and the process is repeated. By the time the second volume of rock has been cooled, the first is back to temperature, so the wells remain in continuous use.



This is easier described than carried out. Depths are usually several kilometres, at the limit of current technology for directional drilling, which is required at depth in this application. However, the concept shows great promise. The dry geothermal energy resources of Australia are more than sufficient to power the country [23], but most of these are centred on the Cooper Basin in northeast South Australia.

[23] One document sighted in researching this paper said "for 7000 years". This should be long enough for most of us!

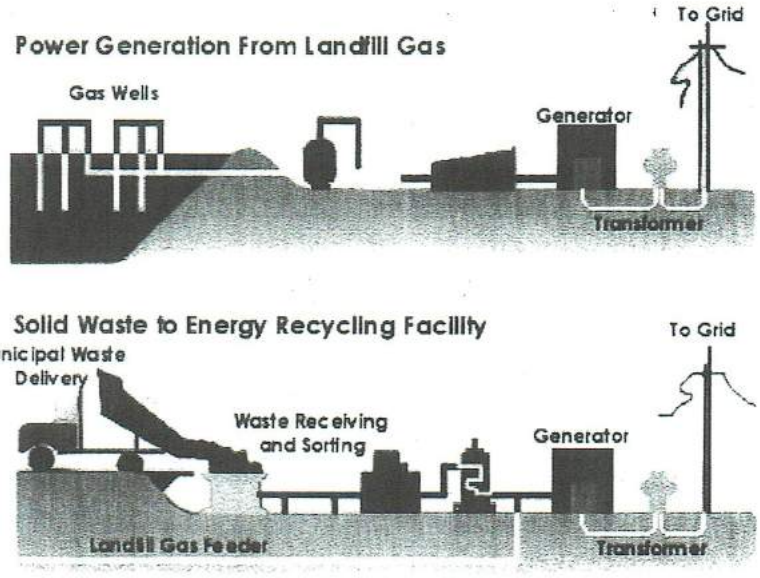
As the diagram shows, there is little prospect of geothermal energy making a contribution to WA's energy demands.



Biomass, Biogas

Burning wood, making charcoal from wood, producing ethanol, burning bagasse in sugar-growing regions – all these are long-standing renewable energy technologies. Most have been practised in WA at some time. There is a growing trend to revert to these technologies in advanced countries, and to expand their use in developing countries.

One method worthy of discussion is the production of energy from the anaerobic digestion of municipal waste. Properly managed landfill sites can produce a combustible gas – "landfill gas" – to fuel a power station. The principle is explained



in the following diagrams (from "Australian Energy News"):

CASE (WA's Centre for the Application of Solar Energy) has successfully applied these principles in a municipal waste dump in Makassar, Sulawesi. A strong benefit of this project was the breakdown of the largely organic waste into an effective fertiliser. The energy produced on site from biogas was sufficient to power waste sorting equipment, improving the digestion process.

There are many opportunities for application of biogas and biomass technologies in WA. The advent of large-scale sugar production in the Ord River Irrigation Area Phase 2 expansion, and the planting of tracts of oil mallee to overcome sa-

linity as well as provide an energy source, are two examples of near future use of biomass.

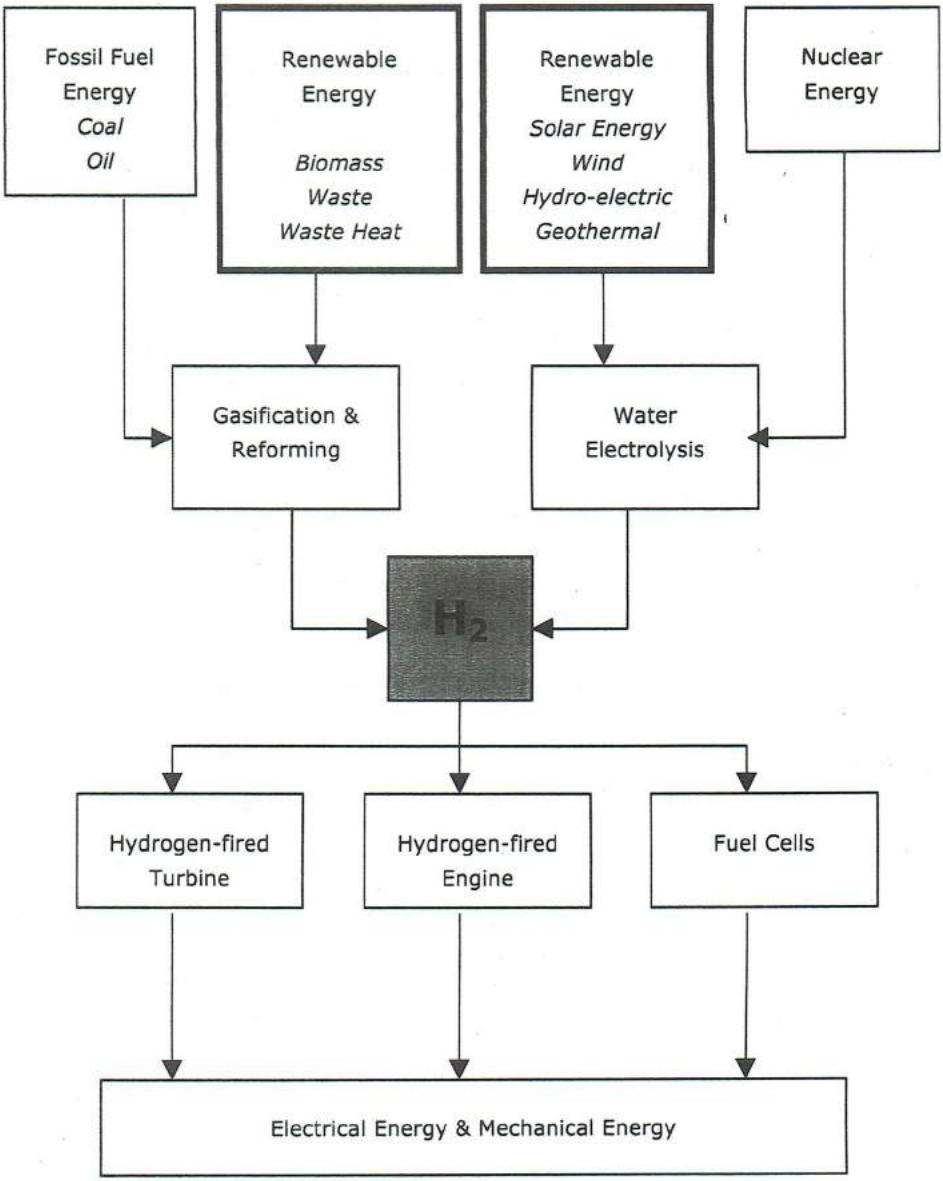
The Hydrogen Economy

Hydrogen reacts with oxygen to produce water and energy. Hydrogen can be produced by electrolysis of water, requiring electrical energy input. The electrical energy can be generated renewably. There are no significant pollutants in the process, and no CO_2 produced. This is the promise of "the hydrogen economy" to the future of the global environment.

The hydrogen economy *per se* is broader than the description above. Hydrogen can be created by means other than electrolysis, and of course electrolysis can receive electrical energy from fossil and nuclear sources. Hydrogen is transportable by pipeline, but its boiling temperature is very low, requiring advanced cryogenic technology and materials if it is stored as a liquid.

A simple representation of the hydrogen economy is shown on the next page [24]:

[24] Extracted from Japanese Society of Mechanical Engineers' Newsletter, January 2000.



"Greens" would discount the role of fossil fuels and nuclear energy in the hydro-

gen economy. However, these technologies presently produce power at lower cost than renewables at this time, meaning that they could be the basis for initial supply of hydrogen while the hydrogen distribution and storage infrastructure is built for the longer term. The reforming process for producing hydrogen and using fossil fuels to generate electricity for electrolysis both generate CO_2, so these alternatives do not assist the problems of GHG emission.

Hydrogen can act as a replacement fuel for motor vehicles. BMW has embraced this alternative by developing a series of engines for their existing line of motor vehicles. BMW's approach uses reciprocating engines modified for hydrogen, with insulated liquid hydrogen fuel tanks. Several engine sizes have been produced, and one was demonstrated at the 2000 Sydney Motor Show (a BMW 750hL). BMW believes that turning to alternative energies will reduce CO_2 emissions and reduce the transport sector's exclusive dependence on oil. Their vision is to continue with familiar technology adapted to hydrogen [25]. BMW expects to see the start of a hydrogen supply infrastructure in some major cities in Germany in the next decade, to support the introduction of their hydrogen-fuelled vehicles.

An alternative potentially suited to both stationary and mobile applications for using hydrogen to generate electrical energy is the fuel cell. The fuel cell effectively reverses the process of electrolysis, producing DC electricity and water vapour. Some fuel cell technologies operate at very high temperatures, requiring ceramic materials. The cells offer the potential for very high efficiencies, especially at higher power levels. Fuel cells are presently not compact, so their integration into cars will not take place for some while yet: initial mobile applications of fuel cells will be in trucks and buses [26]. Three such buses, designed by Mercedes-Benz, will be on trial in Perth during 2001.

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[25] BMW Magazine 4/2000, p111

[26] Dr Burkhard Göschel, BMW Director, BMW Magazine 4/2000, p99

Static fuel cells could be installed in households, supplied with hydrogen by pipeline or mobile (liquid) tank. Coupled with other on-site renewable energy technology (particularly PV), the fuel cell could support the house electrical demands and provide a source of heat and some fresh water.

There seems to be widespread agreement that the hydrogen economy is the way ahead for energy supply, coupled to renewable energy technology. WA should play its part in developing this concept for the longer term.

Other Technologies

There are other, more exotic, renewable energy technologies under consideration or development. None is likely to affect life in WA in the next decade. Should the reader wish to review these, a suitable starting point is the Internet site maintained by the Australian Greenhouse Office [27].

Technologies Relevant to Western Australia

Of the technologies discussed above, a few are relevant and applicable in this state. With our abundant wind and solar resources, wind power, photovoltaic and solar thermal are obvious candidates for widespread application and future research. Tidal, wave and ocean current technology could be longer-term prospects. Biomass and biogas will also play important roles.

Future WA activity in renewable energy technologies should focus on these sources of renewable energy. The State is also a leading source of "balance of system" technology, particularly batteries, inverters and system controllers.

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[27] http://renewable.greenhouse.gov.au/